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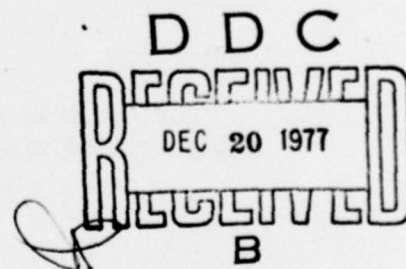
THE HAZARD RANKING AND ALLOCATION METHODOLOGY:
ASSEMBLY OF THE HAZARD ESTIMATION DATA BASE
FOR AIR AND SURFACE WATER POLLUTANTS

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This report presents current methods for preparation of data inputs for chemical pollutants associated with air and surface water pollutants. In several cases where data sources are not available, starting estimates, or default values are supplied. HRAM requires numerical declarations of the uncertainties associated with data inputs. Recommended values of these uncertainties are presented.

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This report describes the data base assembly techniques for a systems analysis with several unusual and unproved features. Thus, the author has set out upon new and relatively unfirm ground. Helping to provide some footing are Dr. Jack C. Dacre, who gave several cogent pointers on mammalian toxicology and philosophy; Mr. J. Gareth Pearson, who provided similar service in aquatic toxicity; CPT John P. Glennon, who as research area manager for munition studies has made several suggestions, particularly about the extrapolations of data from central measures of toxic effects. Special thanks is extended to Dr. Stephen L. Brown, who was the leader of the Stanford Research Institute group that developed the analysis, and has continued to make suggestions as to data base formation. Most recent of these is reflected in the uncertainty assignments for LMD (Section II-A).

TABLE OF CONTENTS

ACKNOWLEDGMENTS	1
I. INTRODUCTION	5
A. An Overview of HRAM	5
B. Data Representations	7
C. Uncertainty Representations	9
II. TRANSPORT MODEL PARAMETERS	10
A. LMD	10
B. SMF	11
C. SMT	12
D. SMC	14
E. R	15
III. DEMOGRAPHIC FACTORS	15
A. Surface Water Situation	15
B. Air Situation	17
IV. SOURCE ESTIMATIONS	19
V. VALUE OF EFFECTS	21
VI. EFFECT RISK: NONHUMAN	22
A. Crops	23
B. Fish	23
VII. EFFECT RISK: HUMAN	24
A. SMB	24
B. Carcinogenic Effect	25
C. Chronic Effects	26
D. Acute Effects	28
LITERATURE CITED	33
APPENDIX: Sample Data Sheets from Cited Reports	35
LIST OF ACRONYMS	41
DISTRIBUTION LIST	44

LIST OF FIGURES

1. Velocity-Flow Curves for the New River - Radford to
Glen Lyn, VA 13
2. Sample Tabulation of Data from "Census of Agriculture" 20

LIST OF TABLES

1. Uncertainty Representations 9
2. Computation of Fish Valuation 21
3. Doses for Effects Handled by HRAM 25
4. Data Translations from a 14-Day Mammalian Study to S...CTG and
S...CTR and Suggested Uncertainty Assignments 29
5. Data Translations from a 90-Day Mammalian Study to S...CTG and
S...CTR and Suggested Uncertainty Assignments 30

I. INTRODUCTION.

The Hazard Ranking and Allocation Methodology (HRAM) is a systematic approach to assist in the cost-effective evaluation of potential research projects for munitions standards and installation restoration studies. These studies are typified by a large number of compounds to consider (of the order of 100-200), sparse background information existing about their toxic properties, and the potential to schedule research efforts far in excess of financial resources.

HRAM was developed by ^{NR}Stanford Research Institute personnel under Contract DAMD 17-75-C-5071. An overview of the concepts and approaches involved are briefly discussed in the next section; however, the contract final report (1) should be consulted for a thorough review.

HRAM is computer-executed, hence, data inputs to be processed must be in a format compatible with program algorithms. This often involves a data translation or derivation from existing information. In some situations, a reasonable starting assignment of values where sources are absent (default values) is required. Data sources involved cover a wide spectrum of disciplines, such as hydrology, demography, and toxicology. Moreover, HRAM requires a numerical declaration of uncertainty associated with each datum. Most of the approaches to developing data inputs and assigning uncertainties do not have precedents.

This report presents currently used methods for the construction of the HRAM data base. It is designed to assist a user as to where data is available, what data translations, derivations or approximations may be necessary, and as to what uncertainties should be assigned. In part, this report is based on the contract final report (1) recommendations; in part, upon the author's experience; and in part, upon opinions of Laboratory personnel. The methods and especially the uncertainties presented, are quite tentative and subject to change with continued experience.

The data bases discussed are associated with pollutants discharged into surface waters and air. The base associated with aquifer flow of pollutants is under development, and when processing methods are developed, a separate report will be prepared.

A. An Overview of HRAM*.

At a munitions plant where a pollutant is identified, the pollutant discharge is characterized in terms of a mass/time emission rate. Generally, long-term averages are used. A receiving medium is specified, which in this case is predominately surface water. Population types of interest are defined; for surface water, these are

* This overview was prepared for a munitions pollution problem definition study currently in preparation. The emphasis therein is on surface waters.

humans and fish. Rational groupings and individual sizes of populations are identified. For humans, these groupings are typically communities serviced by a water utility which draws from the receiving medium; for fish, a measure of the number of fish in a reservoir or a section of river. Surface water flow rates and travel times from the pollutant source to the target population groups are estimated. For each chemical, an overall first-order environmental decay constant is estimated.

With the above information, a concentration experienced by each target population group is computed. For each population type, the incidence of specified effects is related to water concentration as derived from toxicity data. Each effect is a "yes-no" response to the pollutant as opposed to a gradation from some mild response to mortality. As currently employed for humans, an acute mortality, chronic carcinogenicity, chronic mortality and chronic morbidity characterization of effects has been adopted. For fish, the effects are acute mortality or chronic mortality (or some identifiable manifestation of equivalent adverse value). The relations involved are linear; thresholds, if known, can be included. Finally, each adverse effect is assigned an economic value. The hazard for a given chemical, involves the computations of summations:

$$\sum \text{Plants} \sum \text{Types} \sum \text{Groups} \sum \text{Effects} \quad (\text{effect value}) \times (\text{effect incidence}) \times (\text{population group size})$$

If all the factors which enter into a hazard computation were well known, within the limits of the analysis rigor, the hazard would be accurate. These factors are seldom well known, if at all. If they were, additional research would be unnecessary. Thus, the allocation approach considers research as a series of projects which strive to increase the accuracy of a hazard estimate. As a quantitative, albeit subjective measure of accuracy that can be attached to the various factors involved in a hazard computation, "uncertainties" are specified. An uncertainty is conceptually the estimate of a "two-sigma" range (two standard deviations) about a factor estimate, assuming that such a range has statistical sense.

There is no a priori rationale upon which to base uncertainty. Thus, an arbitrary assignment of these based on a definable level of knowledge is used.

A proposed research project can be processed by HRAM if: (a) one or more factors involved in hazard estimations will have reductions in uncertainties; (b) the post-project uncertainties are specified; and (c) the project cost is specified.

The allocation criteria involved is to maximize the reduction in uncertainty by proposed research per dollar cost of the research. A detailed discussion of the rationale is beyond the scope of this section; it can be demonstrated that this criteria is not only cost-effective in terms of research, but is cost-effective in terms of typical abatement-cost relations.

A deterministic approach to computing the uncertainty of hazard based on the hazard factors and their uncertainties has not been defined. As an approximation, a "Monte-Carlo" sampling routine is used. This involves the random selection of numerical values for each factor based on the factor estimate, uncertainty, and presumption of a distribution, and the subsequent computation of hazard. This is repeated until a reasonably stable mean and standard deviation for the estimated hazard is attained. This procedure is repeated for each proposed research project, substituting the uncertainty expected after the research for those prevailing if the research was not done.

The hazard ranking computations include provisions for risk estimation (the estimated incidence of an effect to a given member of a population group). This provides the manager the means to judge the research projects as allocated to identify those which are favored more on the basis of large target populations as opposed to high incidence. However, the trade-off involved for such an analysis is subjective.

B. Data Representations.

HRAM operates on three sets of data files. The first file is a fixed set called TSTIA. TSTIA provides alphanumeric input to HRAM to allow for interpretation of data indices for processing. TSTIA includes the designators for the transport media in which pollutants appear and present a hazard. Three designations are currently accepted: AIR for airborne transport; GWT for transport in ground-water (aquifer flow); and H2O, for surface water transport.

The second data file includes data inputs and associated uncertainties required for hazard computations. These data elements are indexed in terms of one or more of the following qualifiers: transport medium, location, chemical, effect, population type and group index. Where these indices are to be supplied, they are herein represented as med, loc, che, eff, pop, and nnn respectively. The first five are alphanumeric quantities of 1 to 3 characters and are left-justified. The last is integer and is right-justified.

The third file, which is not discussed in this report, includes data on proposed research programs that are to be ranked.

The specific indices for transport medium are in file TSTIA. All other indices are defined by the user. For example, a location may be HOL, which represents Holston Army Ammunition Plant. This is for user convenience, as far as HRAM algorithms are concerned, H, HO, HST, XYZ, or H12 would be perfectly acceptable. Designations of location and chemical are not discussed in further detail.

Population type indices currently employed are:

HUM - Humans

FSH - Fish, and

CPS - Crops.

Specific effects currently employed are:

ATX - Acute toxic effect leading to death or equivalent social-economic sickness or disability.

CTR - Mild or recoverable effect caused by chronic exposure.

CTG - Death or equivalent social-economic sickness or disability caused by chronic exposures.

Cbb - Occurrence of carcinogenesis. There is no qualification as to the severity of the disease.

FKL - Fish kill due to acute exposure.

CFS - Fish kill or equivalent severe response (tainted flesh, loss of reproductive ability) due to chronic exposure.

CYL - Loss of crop yield due to acute exposure to an air pollutant. Moreover, a given effect designation must be unique to one population type.

Specific data elements identifiers are:

LMD - First order environmental loss rate constant.

SMF - Surface water flow rate.

SMT - Surface water travel time from point of pollutant introduction to population group location.

SMC - Conversion factor of air pollutant source to ambient concentration.

Nbb - Population group element.
 Qbb - Discharge rate of pollutant.
 Rbb - Water treatment removal factor.
 SMB - Concentration to dose conversion factor.
 Sbb - Slope of an effect-risk relation.
 Bbb - Threshold of an effect-risk relation.
 Vbb - Value of an adverse effect.
 Cbb - Concentration of pollutant in transport medium.

Each data element discussed is headed by the identifier followed by the indices that specifically define it. For example, the data element "human population group subject to a surface water pollutant in the vicinity of a given location" is noted as NbblocH2OHUMnnn. The designations "loc" and "nnn" indicate information that is to be supplied to complete the data element identification (such as NbbHOLH2OHUMbb4).

Finally, data elements must include units. In most cases, these are scientific units. In certain cases, the units are artifacts used by the HRAM algorithms to differentiate between population types.

C. Uncertainty Representations.

Three options are open for the expression of uncertainty: a percentage uncertainty; an absolute uncertainty; and a geometric uncertainty. Table 1 shows their representation and their significance in terms of a "two-sigma" range. The formats below are used in the report. Geometric uncertainties are used in the majority of assignments.

TABLE 1. UNCERTAINTY REPRESENTATIONS

<u>TYPE</u>	<u>FORMAT</u>	<u>TWO-SIGMA RANGE^a</u>
Percentage	+nnnnnP	$D*(1-U/100)$, $D*(1+U/100)$
Absolute	+nnnnn	D-U, D+U
Geometric	*nnnnn	D/U, D*U

a. The data element numerical value is D, the uncertainty numerical value is U.

II. TRANSPORT MODEL PARAMETERS.

Transport models attempt to provide a rational means of converting pollutant discharges in mass/time to ambient concentration in mass/volume. Such models also account for environmental processes that can occur during pollutant transport. Since such processes are poorly, if at all known for the pollutants encountered, HRAM does not rely upon detailed models. Moreover, HRAM algorithms only processes the disappearance of a primary pollutant. No specific method exists to process the appearance of environmentally transformed species.

For surface water, a subroutine H2OMOD is executed internally in HRAM, which in terms of data elements (less indices) has the algorithm

$$C = \frac{(Q)(R)}{(SMF)} \exp(-LMD \times SMT) \quad (1)$$

where C is compute for each population group. For each indexed group, a SMF and SMT must also be defined. R is defined for each chemical and population type; otherwise a default value of 1 is applied. LMD is defined for each chemical.

In air, HRAM relies on an independently executed air dispersion model to derive an ambient air pollution concentration value, SMC, that would be attained from source or sources, each of 1 g/sec. Such a model, SRICDM, was supplied with HRAM software (2). SRICDM is a variant of the environmental Protection Agency CDM model. The major difference is that SRICDM processes four quarter-year meteorological sets of data rather than one set of annual data. This data consists of the probability of occurrence for wind direction, velocity, and stability category. This is obtained from the National Oceanographic and Atmospheric Administration, Asheville, NC. Typically, data from the nearest weather station to the location of interest is supplied.

HRAM will also accept concentrations in the format Cbbchelocmedpopnnn as input and override any internal computation. Hence, environment transport models other than those cited can be used.

A. LMD

LMDcheH2O (units in yr^{-1})

LMD represents an overall first-order kinetics disappearance rate of a chemical in the surface water environment. Presupposed is that different mechanisms operate independently of each other, such as that for n mechanisms,

$$LMD = \sum LMD_i \quad (2)$$

A default value of $LMD = 15 \text{ yr}^{-1}$ is recommended. This is indicative of a compound that is moderately degraded in the environment. As a basis of comparison, a conventional municipal sewage with a BOD_{20}^* indicative of 70% satisfaction would be assigned an LMD of 80.

Since LMD and SMT are within an exponential term, the method of expressing their uncertainty significantly effect the final hazard distribution. HRAM seeks to have hazard distributions as approximately log-normal. To minimize skewness caused by the exponential term, a percentage uncertainty is recommended for use with LMD. As indicated in Section C, SMT is generally fairly well known or approximated. The choice of its uncertainty expression is not as severe. A default uncertainty for LMD of 95% (+95P) is suggested. This tends to understate the highest value expected for LMD (in the suggested default case, 29.25 yr^{-1}), but due to the exponential, the understatement is often academic.

B. SMF

SMFlocpopnnn (units in ℓ/yr or ft^3/sec)

SMF represents the surface water flow available for dilution of a pollutant. For humans, SMF is the mean annual flow of surface water. For fish, the 7Q10** flow is used as a measure of dilution at low flow.

In studies to date, the rivers are large enough to be included in the United States Geological Survey (USGS) gage network. The Water Resources Division of USGS for each state should be consulted for the latest copy of the state "Water Resources Data," which is issued yearly. Gage stations can be identified which are in the vicinity of population groups of interest. "Water Resources Data" also presents the historical mean flow of streams at the gage stations (see Figure A-1).***

Most Water Resources division offices, will, upon request, either supply computed 7Q10 flow rates for gage stations or will send copies of the "Streamflow Summary Sheets" of low flow records at stations (see Figure A-2). These sheets include the lowest mean consecutive 7 day flow for each year of record. Rank the yearly flows from lowest (1st) to highest (n^{th}). The 7Q10 is approximately the flow ranked integer $(1+n/10)$.

With such data, estimates of SMF for human and fish population groups can be made. Some critical assessment of data is needed where locations of groups fall between gage stations where large side streams

* Biological oxygen demand satisfied in 5 days at 20°C .

** The statistic of mean 7 day consecutive low flow with a expected occurrence of once every 10 years.

***See Appendix.

occur. In the case of dammed impoundments, the river flow used is that which would be noted if the dam were not present. For such data, A U of *1.1 is suggested.

If a 7Q10 value is not available, a default value of one-fifth mean flow is suggested with a U of *1.5.

In the case where fish populations are close to source discharges, mixing may not be complete, and other criteria may be needed for SMF estimates and attendant uncertainty assignments. These are too diverse for discussion.

C. SMT

SMTlocpopnnn (units in days)

SMT represents the travel time in surface water of a pollutant from its point of entry into the environment to the indexed population group.

The SMF data cited previously is needed as well as gage station measurements of stream cross-section vs. stream velocity. These measurements are required for the generation of gage curves and are entered onto Form 9-275 (Discharge Measurement Notes), see Figure A-3. Upon request, the Water Resource Division offices will supply these forms.

SMT will generally be calculated piecewise based on the number of gage stations and impoundments involved. Distances are determined from the pollutant source to population groups. The most typical method is to use "river mile" designations which are generally listed with gage station locations, and on pollution discharge permits. In the absence of these, distances may be measured from maps.

Stream velocity data are computed on Form 9-275, hence stream flow-velocity curves can be constructed for each gage station. Figure 1 shows examples of such curves. From the averaged station velocities at mean and 7Q10 flow, the time of travel can be computed within the stream section included. This should be done critically, as gage-station locations may not be representative of conditions prevailing in the stream section.

Where impounded lakes exist in the section of interest, travel time for human populations may be estimated as $2/3$ (mean lake capacity/mean flow). Lake capacity data is available in "Water Resources Data." This approximation is based on a study of Fort Loudoun Lake of the Tennessee River by Wilkinson (3).

Travel time to fish in impoundments is arbitrarily set at mean lake capacity/mean stream flow. Again, where fish population groups are

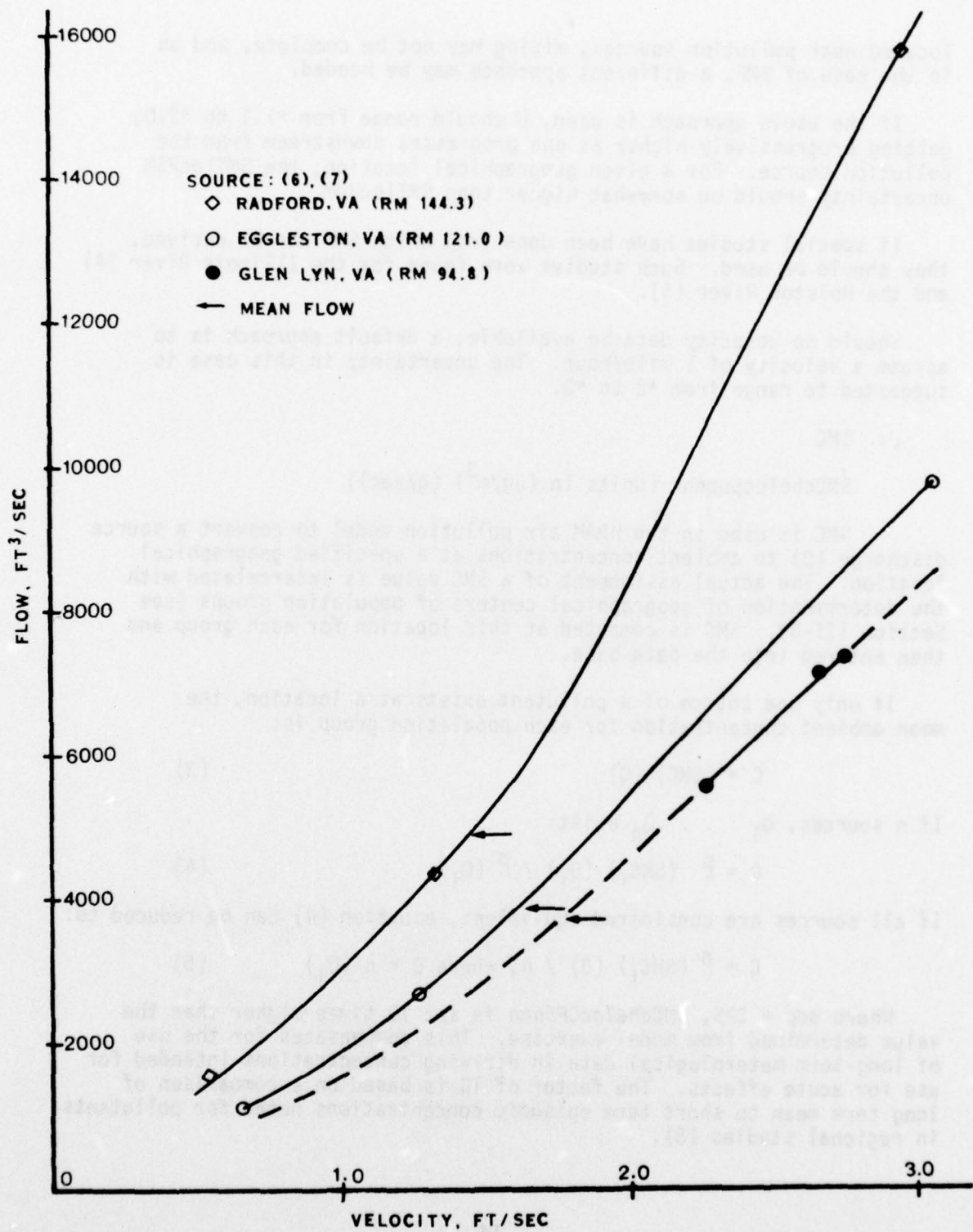


Figure 1. Velocity-Flow Curves for the New River - Radford to Glen Lyn, VA.

located near pollution sources, mixing may not be complete, and as in the case of SMF, a different approach may be needed.

If the above approach is used, U should range from *1.1 to *2.0, getting progressively higher as one progresses downstream from the pollution source. For a given geographical location, the SMTlocFSH uncertainty should be somewhat higher than SMTlocHUM.

If special studies have been done from which SMT can be derived, they should be used. Such studies were found for the Illinois River (4) and the Holston River (5).

Should no velocity data be available, a default approach is to assume a velocity of 1 mile/hour. The uncertainty in this case is suggested to range from *2 to *3.

D. SMC

SMCchelocpopnnn (units in $(\mu\text{g}/\text{m}^3)$ (g/sec))

SMC is used in the HRAM air pollution model to convert a source discharge (Q) to ambient concentrations at a specified geographical location. The actual assignment of a SMC value is interrelated with the determination of geographical centers of population groups (see Section III-B). SMC is computed at this location for each group and then entered into the data base.

If only one source of a pollutant exists at a location, the mean ambient concentration for each population group is:

$$C = (\text{SMC}) (Q) \quad (3)$$

If n sources, $Q_1 \dots Q_n$ exist:

$$C = \sum (\text{SMC}_i) (Q_i) / \sum (Q_i) \quad (4)$$

If all sources are considered equivalent, equation (4) can be reduced to:

$$C = \sum (\text{SMC}_i) (Q) / n, \text{ where } Q = n (Q_i) \quad (5)$$

Where pop = CPS, SMCchelocCPSnnn is set 10 times higher than the value determined from model exercise. This compensates for the use of long-term meteorological data in deriving concentrations intended for use for acute effects. The factor of 10 is based on a comparison of long term mean to short term episodic concentrations noted for pollutants in regional studies (8).

The uncertainty assigned to SMC will reflect the accuracy of source configuration and that of model validity. Model validity is related to distance, which in turn, to a large extent, determines SMC. Where source data are considered accurate, a rough guideline for pop=HUM is:

$$U = * (1.0 + .02/SMC) \quad (6)$$

For pop=CPS,

$$U = * (1.0 + .2/SMC) \quad (7)$$

E. R.

RbbCHEHUM

R represents the residual fraction of a pollutant in water after treatment for drinking. A default value of 0.25 with U of *3.2 is recommended. The default value represents a rough approximation based on total organic carbon in drinking water as compared to that in a relatively slightly polluted source.

III. DEMOGRAPHIC FACTORS.

At present, populations considered in HRAM are: for surface water pollutants, humans and fish; and for air pollutants, humans and crops. Strikingly different methods and sources are used to develop estimates for each. Moreover, the procedures described here interrelate with those factors discussed in Part II.

The "units" cited with each population type are not scientific units. They provide the means by which HRAM algorithms recognize different types. Any three character alphanumeric code may be adopted for a population type. For humans, the unit "CT" is used; for fish, "\$F" is used.

A. Surface Water Situation.

Nbbloch2OHUMnnn (units in CT)

The Department of Health of each state maintains records on water supply sources and population size served. Telephonic conversation often suffices to get this information; some states will supply published data for reference purposes. The actual water works involved, based on the state involved, can be municipalities, quasi-governmental utilities such as Public Utility Districts or County Districts, or private companies. In some instances, water comes from dual sources, such as wells and surface water. The water works personnel can be contacted directly for a breakdown of supplies; state personnel often have the contacts available. Populations can be pro-rated on the percentage use of surface

water. U is set at *1.01, since the data so gathered should be quite precise.

NbblocH20FSHnnn (units in \$F)

Two practical problems exist in deriving these estimates; fish are generally not uniformly located in a section of a stream, and the populations involved are highly heterogeneous. Different streams have different fish, the fish are of different quality and of different size. Thus several artifacts are involved in estimations.

The general approach is to define groups in terms of compartments of a stream system. One group may represent fish in the vicinity of a pollutant outfall (perhaps a stretch where imperfect mixing of the wastewater plume and the stream occur). A second group may represent all fish in the stream for a given distance further downstream. Typically, impoundments are assigned as separate population groups since estimation procedures are different for impoundments than for free-flowing water. The midpoint of each compartment is considered as the point of reference for estimates of SMT and SMF. Where the compartment is free-flowing water, the estimated time of passage through the compartment is needed (the procedures for SMT estimation provide these times).

The "\$F" is considered equivalent to 1 pound of fish. This relation reflects an effect valuation problem; existing data are on a per weight basis.

For impoundments, a default value based on a fish density of 600 \$F/ha is suggested. This density is based on yield studies in the Chickamagua Lake of the Tennessee River (9). For area computations, "Water Resources Data" provides stage level information (see Figure A-4) of impoundments in tables of capacity versus stage. Two such data sets should be selected which bracket the average capacity. The surface area is computed as:

$$\frac{\text{Capacity 2} - \text{Capacity 1}}{\text{Stage 2} - \text{Stage 1}} \quad (8)$$

For this default situation, a U of *2.3 is suggested.

If fish yield data are available for impoundments of concern, they should be used. However, the experience to date is that such data are scant.

For free-flowing streams sections, a default value based on a fish density of 1.0×10^{-3} \$F/ft³ (2.8×10^{-5} \$F/m³) is recommended. This is based on tenuous data, a catch on the Holston River of 29.9 kg/ha (9). The river in the vicinity of the catch had a mean depth of 1 meter.

The catch mass/surface area and depth translate to 2.2×10^{-4} lb/ft³ (\$/ft³). However, the Holston River is not considered in good ecological condition; more fish could be supported. Hence, a higher value is adopted for default purposes.

Use of fish density requires an estimate of the volume of water in a compartment. This is computed as the product of SMF and the time of passage in a compartment.

A U of * 2.3 is suggested for assignment.

B. Air Situation.

NbblocAIRHUMnnn (units in CT)

The first problem encountered with this factor is where to define a limit for HRAM model processing. Air pollution dispersion models will compute a finite ambient concentration at any distance from a source. But at long distances (say 20 km), geographical considerations and model parameters render such results as meaningless. As a rough rule of thumb, a limit is recommended at a SMC of .02 $\mu\text{g}/\text{m}^3/\text{g}/\text{sec}$. The geographical extent of this SMC contour may be traced after computation for selected grid points about a source.

Topographic maps are useful for this purpose and for the definition of populations. Maps of scale 1:24000 are recommended, and are available from the U.S. Geological Survey upon specification of the appropriate sheets. State code maps are supplied free of charge by the USGS. From these the needed sheets can be identified and ordered. These topographic maps include a Universal Traverse Mercator (UTM) coordinate grid system with a 1 km spacing. It is recommended that source and hypothetical receptor locations be defined according to this grid system.

Resort is then made to Bureau of the Census data. This is available in two different ways based on the area involved. If the area is within a Standard Metropolitan Statistical Area (SMSA), a preprepared report is available. Therein, the SMSA is sub-divided into tracts; tract data can be used directly for population sizing. If the area is outside a SMSA, a report must be assembled; the Bureau charges for this. Data is presented on a county basis. A map is supplied, which lists the sub-areas, called enumeration districts (see Figure A-5) for which population data are collected. The map typically costs about \$5, the population data cost is on a graduated basis of \$2 per 75,000 persons. Thus, a report for a county with 177,000 persons would cost about \$11.

Once the census data and maps are assembled, centers of enumeration districts or tracts may be identified on the topographic maps. In

urban areas, where enumeration districts are closely bunched,* several districts may be combined and a center assigned. Then, based on the grid coordinate for each center, a value of SMC is computed.

On the other hand, where an enumeration district covers a large area, the district can be subdivided. One method of subdivision is to use 2 km x 2 km grid squares. Populations in each square can be roughly approximated by counting the number of homes (on a topographic map, these appear as solid black squares) in each grid and multiplying by 4. This can be adjusted by comparing the rough count to the district count.

Since the number of computations HRAM executes is roughly proportional to the number of population group indices, which determines the execution time, a limited number of groupings is desirable. As a rough rule of thumb, about 10 groups per pollutant is satisfactory. Thus, counted tracts or districts, or portions thereof can be combined based on similar values of SMC, such as those which have a SMC between .05 and .06 ($\mu\text{g}/\text{m}^3$)/(g/sec).

This works best for locations with one pollutant or several pollutants which emanate from the same stacks. Should multiple pollutants from different sources occur, a "trick" can be used to maintain small data sets. This involves defining the same location with a different code for each pollutant. For example, for methyl nitrate discharges, Holston Army Ammunition Plant could be identified as HOL; for acetic acid discharges, it could be identified as HLN. Then two sets of SMC and N could be defined, each involving populations grouped in terms of SMC for each pollutant and "alias" location.

Values of U assigned are suggested to range from *1.01 to about *1.2 based on the detail used in estimates and the amount of grouping of individually estimated population elements.

$NbblocAIRCPShnn$ (units in m^2)

This population group is expressed in terms of cultivated area. A crop index assignment does not have to be correlated with a human index assignment. However, it must correlate with its SMC assignment.

The same cut-off as used for humans may be used to define the geographic area for crops. However, a grid method of analysis is suggested. This involves dividing the entire geographical area in 2 km x 2 km grids according to the UTM grid. Each map grid can be viewed and the percentage of open land estimated by excluding forest (which

* The separate districts are usually not delineated on county maps. More detailed maps of urban areas are available, if desired, at a charge from the Bureau of the Census.

is colored green), built up area, mines, land too steep for tilling or water features from each 4 km² area. This provides an "unadjusted" area for each grid.

The adjustment factor is derived from county data supplied in the "Census of Agriculture" (Section 2 of each state's volume). Figure 2 is a sample of this data. From Table 1 therein, a multiplying adjustor is computed as:

$$\text{Adjustor} = \frac{(\text{Harvested Cropland})}{(\text{Land in Farms} - \text{Woodland})} \quad (9)$$

This should indicate the percentage of open land that is actually harvested cropland.

As with human populations, a limited number of groupings is recommended. Where several pollutants are involved at a location, the "trick" cited in the previous section may be used.

IV. SOURCE ESTIMATIONS.

Qbbchelocmed (units in kg/yr)

Several tentative approaches have been developed based on the "depth" of data available for estimates. The situation which most closely matches the situation should be used. The uncertainty may be shaded between situations. Q is evaluated based on full production. The evaluation of Q is intended to cover the situation of an installation at "steady state" conditions. Short-term happenings such as start up, dumps, or malfunctioning processes are not considered.

Default values (no data exist at all) are:

If med = H₂O. Q = 100 kg/yr and U = *20. If med = AIR, Q = 1000 kg/yr and U = *32. Air pollutants have not been characterized as well as water pollutants, and large amounts may be more likely to be overlooked.

The material is raw material or product. At a capacity level fraction f where q kg/yr are used or produced,

$$Q = q / (10^4 f) \text{ and } U = *10, \quad (10)$$

This is based on a rough estimate of wastage which economically would be allowed.

Sketchy concentration (C) and flow data (F) exist for a water discharge, and the capacity level fraction is f. Then,

$$Q = C * F / f \text{ and } U = *5. \quad (11)$$

Table 1. Farms, Land in Farms, and Land Use: 1969 and 1964

	1965	1964		1965	1964
All farms	2 205	2 390	Number of farms by acres harvested:		
Land in farms	130 127	135 945	50 to 99 acres	59	104
Average size of farm	59.0	56.9	100 to 199 acres	21	34
Approximate land area	264 576	264 325	200 to 499 acres	8	3
Proportion in farms	49.2	51.4	500 to 999 acres	-	-
			1,000 acres and over	-	-
Value of land and buildings	75 452 569	(NA)	Cropland used only for pasture	1 471	1 165
Average per farm	34 218	21 847	or grazing	46 278	28 717
Average per acre	579.83	390.08	All other cropland (see text)	418	(NA)
				6 199	6 378
Land in Farms According to Use					
Total cropland	2 110	2 333	Woodland including woodland		
Harvested cropland	76 932	68 117	pasture	1 261	1 435
	1 829	2 257		26 282	28 961
Number of farms by acres harvested:	24 455	33 022	All other land (see text)		
1 to 9 acres	1 155	1 352		1 555	(NA)
10 to 19 acres	322	423		26 913	38 844
20 to 29 acres	143	187	Irrigated land	12	14
30 to 49 acres	121	154		61	213

20

All Farms

Table 2. Farms, Land in Farms, and Land Use, by Size of Farm: 1969 and 1964

[illegible]

Survey data has been taken over an extended period of time with known capacity. Using the same nomenclature as above,

$$Q = C \cdot F / f \text{ and } U = *1.2 \quad (12)$$

V. VALUE OF EFFECTS.

Vbbeff (units in \$\$/case)

This data represents the cost in a social and economic sense of the occurrence of an effect. The units of "case" must agree with the units assigned to population. Currently, values have a tenuous data background. However, uncertainties are set at *1.01, in that no research would be undertaken to refine these data. It should be noted that considerable economic discussion continues in this field, as value assignment is common concern to similar models.

VbbC, VbbCTG and VbbATX are currently reckoned at \$300,000. This represents a typical estimate of the value of life. A discussion of rationale for such numerical values is found in a report by Gregor (11).

VbbCTR is currently reckoned at \$30,000. This assignment is arbitrary in that the effect CTR is vaguely defined.

VbbFKL and VbbCFS are currently \$1. These values are interrelated with the population basis of fish, as both are reckoned on a mass basis. The computation involved is summarized in Table 2 with values based on fishery replacement costs. A premium is added to include some measure of social satisfaction with the opportunity to have fish available. Other bodies of water have different mixes of fish, but differentiation is not warranted from a managerial standpoint.

TABLE 2. COMPUTATION OF FISH VALUATION

Population Source: (9)

Value Source: (12)

<u>Type Fish</u>	<u>Yield, lb/acre</u>	<u>Value/lb</u>	<u>Value/acre</u>
Sport	32.7	\$3.25	\$106.28
Rough	103.5	0.30	31.05
Forage	102.2	0.17	17.37
	<u>238.4</u>		<u>\$154.70</u>

Average value/lb = \$154.70/238.4 = \$.65

VbbCPS is set at \$.03/m² or \$121/acre. This is based on agricultural statistics (13), which indicate that 330,000,000 acres were used for crops (1969 data) from which the net income of farm operators was \$27.7 billion (1974 data). This converts to \$84/acre. A premium is added which reflects the social cost of providing livelihood for a farmer faced with crop losses from other sources, such as public assistance, rather than having the farmer as a taxpayer.

VI. EFFECT RISK: NONHUMAN.

Sbbchemedpop (units in l/mg-yr (H2O) or m³/mg-yr (AIR))

Bbbchemedpop (units in g/l (H2O) or g/m³ (AIR))

These parameters form a central role in HRAM, since they involve the translation of toxicological information. Toxicology is the most extensive area of research that HRAM considers. Conceptually, these parameters reflect the yearly risk that an individual member of a population will incur an effect due to a given concentration of a pollutant.

The various estimates of Sbbchemedpop are listed in terms of typical refinement of literature descriptions of toxicological data. The first estimate is a default value, to be used in the absence of any pertinent data. Descending estimates indicate increasing more refined states of data. The evaluator should select the situations considered closest to his datum source and use the uncertainties listed as a range in which to assign uncertainty to the datum.

The guidelines suggested have two general assumptions:

a. Unless the most sophisticated studies indicate otherwise, no thresholds are assumed.

b. The basis for Sbbchemedpop is often a cited concentration where 50% of a population is expected to incur an effect (EC50), such as the 96LC50 for acute fish toxicity studies. In such cases, the slope is given by

$$S = 1/(10 \text{ EC50}) \quad (13)$$

This approximation is based on typical shapes of the dose-response curves, and presumes that the extrapolation of interest is through the intercept and the point (.05, .5 EC50). In general, environmental concentrations are at least one order of magnitude below the EC50. The slope should be considered a piece-wise approximation to the lower portion of the curves.

A. Crops

SbbcheAIRCPS (units in $\text{m}^3/\text{mg-yr}$)

This value is supplied to crop failure due to an episodic (about 8 hour) fumigation once during a growing season. Uncertainties supplied are arbitrary.

a. No TLV* data are available. Find vapor pressure at 20°C, call result L. $S = 1/10L$, $U = *100$.

b. TLV data are available and is $L \text{ mg/m}^3$. $S = 1/2L$, $U = *25$.

c. Data exists which gives an EC50 for an effect equivalent to crop loss. If value is L, $S = 1/10L$, $U = *10$.

B. Fish

SbbcheH20FKL (units in $\ell/\text{mg-yr}$)

SbbcheH20CFS (units in $\ell/\text{mg-yr}$)

FKL refers to acute effects, CFS to chronic effects. Aquatic toxicology data typically are more available for the former. Extrapolations are made from acute effects to chronic non-effects by means of an "application factor" which may, depending on the compounds involved, range from 1/10 to as high as 1/1500 in the cases of heavy metals (14, 15). However, HRAM seeks a factor between a acute effect and chronic effect. For purposes of initial estimates, a factor of 15 is employed.

One SMF typifies flows for fish. However, acute toxic effects are associated with low flows where pollutant concentrations increase well above average levels. Chronic toxic effects are associated with mean flows. As indicated in Section II-B, the low flow is employed by HRAM. To compensate for this, the ratio of mean flow to low flow is about 5, and the residual factor of 3 is used between FKL and CFS slopes. If a pollutant is specific to a given stream, the residual factor can be adjusted based on the mean/low stream ratio.

Suggested approaches based on increasing refinement of data are:

(1) For the default situation, $S...FKL = 2 \times 10^{-3} \ell/\text{mg-yr}$ with $U = *100$. $S...CFS = 6 \times 10^{-3} \ell/\text{mg-yr}$ with $U = *250$. $S...FKL$ is based on an assumed 96LC50 of 50 mg/ ℓ .

* Threshold Limit Values adopted for 8-hour occupational exposures to air pollutants by the American Congress of Governmental Industrial Hygienists.

(2) No-effect acute fish toxicity data do exist. If the highest no-effect concentration for the most sensitive species is L mg/L. $S...FKL = .01/L$ l/mg-yr with $U = *20$ and $S...CFS = .03/L$ l/mg-yr with $U = *50$.

(3) Some 96LC50 data exist with little if any background to its conduct. If the 96LC50 for the most sensitive fish species is L , $S...FKL = .1/L$ l/mg-yr with $U = *8$ and $S...CFS = .03/L$ l/mg-yr with $U = *20$.

The following situations correspond to the USAMBRDL aquatic toxicology protocol for laboratory studies (16). The conversions from 96LC50 to S are as stated in (3) above.

(4) A screening acute bioassay has been performed (Protocol Phase I). For FKL , $U = *4$; for CFS , $U = *15$.

(5) A well-performed acute bioassay has been performed (Protocol Phase II). For FKL , $U = *2$; for CFS , $U = *7$.

VII. EFFECT RISK: HUMAN.

A. SMB

SMBchemedeff

SMBs are used to convert concentrations of a pollutant to which human populations are exposed to a yearly dose. This is due to the HRAM concept that hazard is on a per-year basis and the risk-effect relations are typically for a 1 year dosage at a given concentration.

The doses currently used are in Table 3. All geometric uncertainties are considered $*1.01$. Where no dose is specified, the software assigns a default value of 1.

The value of 7 l/yr for SMBcheh20ATX is based on the following scenario:

- (a) One acute effect is presumed per year.
- (b) The duration of an acute effect episode is one day.
- (c) The effect is presumed to occur at a period of stream low flow.
- (d) The ratio of mean stream flow to low stream flow is 5.
- (e) The daily intake of water is 1.4 L.

TABLE 3. DOSES FOR EFFECTS HANDLED BY HRAM

<u>Medium</u>	<u>Population</u>	<u>Effect</u>	<u>SMB</u>	<u>Units</u>
H2O	HUM	C	500	ℓ/yr
H2O	HUM	CTR	500	ℓ/yr
H2O	HUM	CTG	500	ℓ/yr
H2O	HUM	ATX	7	ℓ/yr
AIR	HUM	C	7300	m ³ /yr
AIR	HUM	CTR	7300	m ³ /yr
AIR	HUM	CTG	7300	m ³ /yr
AIR	HUM	ATX	Not used	

Thus, for unit consistency, a value of 7 ℓ/yr is derived. If a pollutant is specific to one stream, the particular characteristics of that stream may be taken into consideration, and a different value derived.

For the factor $SMB_{cheAIRATX}$, a more convenient approach was found to make the exposure adjustment directly in the valuation of S (see Section VII-D).

B. Carcinogenic Effect.

$S_{bbchemedCbb}$ (units in g⁻¹)

The estimation process involved here is unique in that not only is potency involved, but also the probability that the effect exists.

The first two estimation approaches require use of reference 17. This reference details an "activity tree" approach to such estimations, based on molecular structure and experience with similar compounds. Four values are derived; two are an estimate of potency (P) and the probability that a compound of a given structure will be carcinogenic (p(c)). The slope S..C is:

$$S..C = 5 \times 10^{-4} P p(c) \quad (14)$$

The other values are the uncertainties associated with P and p(c).
The uncertainty associated with S..C is:

$$\text{Log } U = ((\text{Log } U_{\text{potency}})^2 + (\text{Log } U_{\text{probability}})^2)^{1/2} \quad (15)$$

The recommended procedures follow below.

The compound is not included specifically in the "activity tree". S..C = 2.5×10^{-5} , U = *81. The S..C is based on a default P of 1 and a default p(c) of 0.05. The U suggested here is somewhat higher than the *69 derived from reference 17 for an undefined chemical. This reflects doubt that potency can be estimated with a U of *20, which is asserted in reference 17.

The compound is included as a class of the "activity tree." Equation 14 is used to determine S..C. Use equation 15 to estimate U, but use a U_{potency} 1.5 times higher than that given.

The final estimation presupposes the execution of a battery of mutant microorganism-revertant studies, commonly called "Ames Tests." such as performed in reference 18. These tests are presumed to refine the estimate of p(c) but not of P. The approach is:

- (a) If TA-100 strain is positive, p(c) = .5;
- (b) For every other strain positive, add .1;
- (c) For TA-100 negative, but n other strains positive, p(c) = $0.1 \times n$;
- (d) For all strains negative, compound is not in "activity tree" of reference (16), p(c) = .005;
- (e) For all strains negative, but compound is in "activity tree, p(c) = .1 p(c)at, the at designating the "activity tree assignment." For these situations, $U = *1.5U_{\text{potency}}$.

No threshold estimation procedures have been developed.

C. Chronic Effects.

SbbchemedCTG (units in g^{-1})

SbbchemedCTR (units in g^{-1})

Toxicological studies of these effects, due to economic, logistical, moral, and legal considerations, are not performed on

humans. Other mammals, such as dogs, monkeys, mice or rats act as surrogates. For this reason, the interpretation of mammalian or toxicological data is quite different from that of fish and crops.

The approach used in HRAM is intended for situations where the human dose from environmental pollutant sources is at least one order of magnitude below that at which effects occur in mammalian studies. As noted in the units, concern is with dose rather than concentration. Where med = H₂O, typical daily dose data from toxicological studies are in mg chemical/kg body weight of mammal. The human dose equivalent is a linear scale-up of the animal body weight to a value of 60 kg for man. The equation applicable is:

$$\text{Human dose equivalent(g)} = 22 (\text{mg/kg dose}) \quad (16)$$

Where med=AIR, typical toxicity data are represented in mg/m³ or ppm of pollutant in air. After conversion of data to mg/m³ (if needed),

$$\text{mg/m}^3 \text{ pollutant} = \text{molecular weight}/24 \times \text{ppm} \quad (17),$$

the human dose equivalent is 7.3(mg/m³ pollutant), units in g.

The procedures devised do not include threshold estimations.

The typical approach to human standards based on mammalian toxicological data is to invoke an application factor to convert the observed no-effect mammalian dose to that allowable for humans. Then, the allowable environmental pollutant concentration can be computed. The application factor (AF) is based on several factors, such as: duration of the toxicological study, the number of species involved, the sophistication of the study, and the similarity of the species physiology where effects are manifested to that of humans.

For HRAM data assignments, the approach presumes that the risk of an CTG effect at an allowable dose for humans is 10⁻⁶. Thus, if a no-effect dose converted to human equivalent dose is L and an application factor of (AF) is specified,

$$S..CTG = 10^{-6}/(AF)(L) \quad (18).$$

Moreover, the following estimations apply:

(a) A commonly reported dosage in mammalian toxicological studies is the estimated dose that causes death to 50% of the test population (LD₅₀). In the absence of no-effect dose information, the LD₅₀/4 is assumed a no-effect dose.

(b) S..CTR and S..CTG are related:

$$(S..CTG) = 0.1 (S..CTR) \quad (19)$$

As in Section VI, the estimates of S..CTG and S..CTR are based on typical literature descriptions of chronic toxicological data. The least refined information is assigned the highest uncertainty.

The default situation is based on an assignment of S..CTG for mercury (or mercury-bearing compounds) and a comparison of the potency of mercury to other compounds. For mercury, an allowable drinking water standard of .002 mg/l has been set (19). Converting this to a yearly dose and assigning a 10^{-6} risk to that dose (1 mg/yr), $S..CTG = 10^{-3} g^{-1}$. Next, mercury is considered more potent than perhaps 97.5% of all other compounds. In the context of the statistical interpretation of U, the S..CTG for mercury would represent the upper limit from that of most compounds, such that:

$$(S..CTG)_{\text{default}} = (S..CTG)_{\text{mercury}}/U \quad (20)$$

A default U of *300 is used. Hence the default S..CTG is $3.3 \times 10^{-6} g^{-1}$. Also, the default S..CTR, by equation (19) is $3.3 \times 10^{-5}/g$. A geometric uncertainty of *300 is also used.

The next situations (Table 4) are based upon the performance of a 14-day (sometimes called a sub-acute) mammalian toxicology study with at least two species. This test has been considered as the least refined study from whose results an extrapolation to no-effect human dose is possible. The application factor suggested is 10^{-4} . If only one species is cited, the uncertainties should be multiplied by a factor of 1.5.

The next situations (Table 5) are based on the performance of a 90-day (sub-chronic) study with at least two mammalian species. The approach is analogous to that in Table 4, except that the application factor is 10^{-3} .

D. Acute Effects.

$$SbbchemedATX \text{ (units in } g^{-1} \text{ (H2O), mg/m}^3 \text{ (AIR))}$$

This parameter characterizes the risk of an adverse effect from a short-term dosage of a compound. The comments in Section C concerning use of animals and human equivalent dose applies. One difference is the use of the concentration units for air exposure.

TABLE 4. DATA TRANSLATIONS FROM A 14-DAY MAMMALIAN STUDY TO S..CTG AND S..CTR AND SUGGESTED UNCERTAINTY ASSIGNMENTS.

<u>Description</u>	<u>Translator*</u>	<u>S..CTG</u>	<u>U</u>	<u>S..CTR</u>	<u>U</u>
No CTG or CTR Effect Observed	L = Highest no-effect dose for most sensitive species	$10^{-2}/L$	*100	$10^{-1}/L$	*100
An LD50 is estimated, but no no-effect dose is available	L = LD50/4, LD50 is for most sensitive species	$10^{-2}/L$	*55	$10^{-1}/L$	*100
An ED50** is estimated, but no no-effect dose is available	L = ED50/4, ED50 is for most sensitive species	$10^{-2}/L$	*100	$10^{-1}/L$	*55
An LD50 and no- effect dose data are available, but not ED50	L = Highest no-effect dose for most sensitive species	$10^{-2}/L$	*33	$10^{-1}/L$	*55
An ED50 and no- effect dose data are available, but not LD50	L = Highest no-effect dose for most sensitive species	$10^{-2}/L$	*55	$10^{-1}/L$	*33

* After conversion to human dose equivalent, equation 16.

**Estimated dose at which 50% of a species population is expected to suffer a CTR effect.

TABLE 5. DATA TRANSLATIONS FROM A 90-DAY MAMMALIAN STUDY TO S..CTG AND S..CTR AND SUGGESTED UNCERTAINTY ASSIGNMENTS.

<u>Description</u>	<u>Translator*</u>	<u>S..CTG</u>	<u>U</u>	<u>S..CTR</u>	<u>U</u>
No CTG or CTR Effect Observed	L = Highest no-effect dose for most sensitive species	$10^{-3}/L$	*33	$10^{-2}/L$	*33
An LD50 is estimated, but no no-effect dose is available	L = LD50/4, LD50 is for most sensitive species	$10^{-3}/L$	*17	$10^{-2}/L$	*33
An ED50 is estimated, but no no-effect dose is available	L = ED50/4, ED50 is for most sensitive species	$10^{-3}/L$	*33	$10^{-2}/L$	*17
An LD50 and no- effect dose data are available, but not ED50	L = Highest no-effect dose for most sensitive species	$10^{-3}/L$	*7	$10^{-2}/L$	*10
An ED50 and no- effect dose data are available, but not LD50	L = Highest no-effect dose for most sensitive species	$10^{-3}/L$	*10	$10^{-2}/L$	*7

* After conversion to human dose equivalent, equation 16.

The physiological effects from acute exposures often reflects a different mode of action than occurs in chronic exposure. With increasing concern for long-term effects, the importance of acute toxicity studies, other than as a starting point for chronic dosing decisions, has diminished.

Generally, acute toxicological information has been available. and reported in terms of an oral or inhalation LD50. Thus, no default values are recommended. The guideline for slope estimation is similar to that for FKL,

$$S..ATX = 1/10L \quad (21)$$

where L is the human dose equivalent of the LD50 in water exposure or the LC50 in air exposure.

If at least two mammalian species are reported, and the values of L are within a factor of 2 of each other, $U = *10$. Based on data validity, variety, and consistency, U assignments are recommended to range from *33 to *5.

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APPENDIX

Sample Data Sheets From Cited Reports

The included figures are reproductions from data sheets that have been obtained in the course of assembling the HRAM hazard data base. The references are listed in the "Literature Cited" section and follow sequentially from the main body of the report.

<u>Figure</u>	<u>Title</u>
A-1	Sample Gage Station Report in "Water Resources Data" (20).
A-2	Sample Low Stream-flow Summary Printout (6).
A-3	Sample Form 9-275, Kanawah River at Charleston, WV (21).
A-4	Sample Reservoir Elevation-Capacity Data for an Impoundment (7).
A-5	Sample Enumeration District Data from 1970 Census (22).

TENNESSEE RIVER BASIN

03490500 Holston River at Surgoinsville, Tenn.

LOCATION.--Lat 36°28'19", long 82°50'50", Hawkins County, on right bank 1,500 ft (500 m) upstream from Surgoinsville Creek and county bridge at Surgoinsville, 9.8 miles (15.8 km) upstream from Big Creek, and at mile 118.7 (191.0 km). Records include flow of Surgoinsville Creek.

DRAINAGE AREA.--2,874 sq mi (7,444 sq km), includes that of Surgoinsville Creek.

PERIOD OF RECORD.--October 1940 to current year. Prior to April 1941 monthly discharge only, published in WSP 1306.

GAGE.--Water-stage recorder. Datum of gage is 1,088.46 ft (331.763 m) above mean sea level.

AVERAGE DISCHARGE.--33 years, 3,753 cfs (106.3 cu m/s), 17.73 in/yr (450 mm/yr), unadjusted.

EXTREMES.--Current year: Maximum discharge, 41,100 cfs (1,160 cu m/s) Mar. 30, gage height, 13.37 ft (4.075 m); minimum, 886 cfs (25.1 cu m/s), Aug. 29.

Period of record: Maximum discharge, 59,600 cfs (1,690 cu m/s) Feb. 18, 1944, gage height, 17.48 ft (5.328 m); minimum, 470 cfs (13.3 cu m/s), Oct. 21, 1941.

Maximum discharge since closure of Watauga Dam on Dec. 1, 1948, 59,300 cfs (1,680 cu m/s) Mar. 13, 1963, gage height, 17.13 ft (5.221 m).

REMARKS.--Records good. Flow partly regulated by four reservoirs (see p. 142). Records of chemical analyses and water temperatures for the current year are published in Part 2 of this report.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2,570	1,010	2,550	6,060	6,270	5,570	17,600	7,100	3,180	4,510	3,420	973
2	2,410	2,590	5,970	8,130	10,700	6,150	13,400	6,980	3,670	4,230	3,850	1,410
3	3,480	2,050	5,510	6,380	14,500	4,760	12,700	7,680	5,880	4,480	2,920	3,310
4	3,710	1,010	4,100	6,380	12,500	3,890	11,600	5,620	5,380	4,250	3,150	4,810
5	1,710	1,760	3,540	5,770	12,900	5,130	10,900	5,160	4,680	2,660	4,630	4,340
6	1,860	2,400	3,050	5,660	12,500	5,420	7,570	7,250	6,960	2,150	4,270	4,040
7	2,010	4,140	1,400	5,500	12,300	3,750	6,680	8,230	4,800	1,440	2,850	2,550
8	3,240	3,440	1,650	3,000	13,000	5,840	7,970	7,240	3,880	3,590	3,630	1,040
9	2,360	4,060	5,940	4,400	9,850	6,570	7,550	9,170	2,960	5,510	2,830	2,700
10	3,300	4,140	7,190	2,900	9,860	5,710	8,480	9,820	3,450	5,370	1,360	3,900
11	3,120	2,250	4,030	4,880	7,270	6,870	6,510	6,340	4,080	5,150	1,800	4,220
12	2,440	1,820	2,480	5,310	8,640	7,750	7,730	6,660	4,890	5,070	5,900	5,480
13	1,010	6,310	2,820	7,860	12,300	17,600	6,190	6,950	5,280	3,970	6,190	3,990
14	1,300	4,070	2,140	11,100	10,100	29,200	5,650	6,580	5,880	4,420	3,400	2,130
15	2,410	4,230	1,450	8,880	9,790	29,900	4,990	7,280	5,070	5,320	2,150	1,660
16	4,210	4,850	2,190	5,720	6,310	16,000	5,060	6,940	4,860	3,950	2,110	2,470
17	2,860	1,140	3,340	6,480	7,780	12,100	3,990	6,820	4,450	4,090	3,630	3,010
18	3,100	1,160	5,480	5,730	8,930	12,600	4,590	4,980	4,770	4,220	2,090	3,510
19	2,300	4,580	4,000	2,770	6,940	12,400	5,930	5,250	6,410	3,850	4,520	4,810
20	1,610	3,170	4,610	7,910	5,830	11,100	3,770	5,480	5,030	2,830	5,680	4,830
21	3,660	6,310	3,190	11,800	5,780	11,600	3,150	4,710	5,900	2,260	5,430	2,850
22	3,550	10,700	2,570	8,020	6,210	10,500	3,340	6,310	7,640	2,260	5,370	2,280
23	1,410	6,230	2,070	6,650	4,770	11,200	3,600	6,080	3,790	3,560	6,100	7,190
24	1,070	5,270	1,850	5,550	7,610	13,300	4,790	3,320	4,600	4,320	4,440	10,300
25	1,050	7,190	2,700	8,640	9,890	12,200	4,350	2,440	5,730	5,100	3,490	6,130
26	1,120	8,650	5,160	15,600	5,060	12,000	5,460	2,850	5,470	5,930	4,090	3,010
27	1,200	7,700	7,100	12,400	4,780	8,440	5,590	4,270	4,510	3,150	4,270	2,300
28	1,450	5,530	11,000	8,360	5,380	9,710	6,350	6,500	4,130	2,430	1,910	2,000
29	1,450	2,420	15,600	6,000	-----	11,200	5,640	5,680	3,110	4,040	1,180	2,020
30	1,260	2,350	9,290	6,950	-----	33,400	5,390	3,690	2,290	3,900	1,710	2,410
31	1,260	-----	5,910	6,640	-----	32,600	-----	4,030	-----	3,660	1,750	-----
TOTAL	69,990	122,660	138,880	217,430	249,750	374,960	206,520	187,450	142,730	121,670	110,120	165,673
MEAN	2,258	4,089	4,482	7,014	8,920	12,100	6,884	6,047	4,758	3,925	3,552	3,522
MAX	4,210	10,700	15,600	15,600	14,500	33,900	17,600	9,820	7,640	5,930	6,190	10,300
MIN	1,010	1,010	1,400	2,770	4,770	3,750	3,150	2,440	2,290	1,440	1,160	973

CAL YR 1974 TOTAL 2,195,700 MEAN 6,016 MAX 26,300 MIN 1,010 MEANT 5,912 CFSMT 2.06 IN.† 27.92
WTR YR 1975 TOTAL 2,047,833 MEAN 5,611 MAX 33,900 MIN 973 MEANT 5,476 CFSMT 1.91 IN.† 25.86

† Adjusted for change in contents in South Holston, Watauga, Boone, and Fort Patrick Henry Lakes.

Figure A-1. Sample Gage Station Report in "Water Resources Data" (20).

STATION NUMBER 0311000

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

NEW RIVER AT RADFORD, VA

YEAR	1	3	7	14	30	60	90	120	183	ANNUAL								
1941	958.00	20	1070.00	21	1480.00	25	1530.00	25	2150.00	29	2520.00	28	2950.00	28	2950.00	24	4280.00	25
1942	640.00	2	762.00	2	943.00	3	589.00	3	1050.00	3	1140.00	2	1270.00	4	1340.00	4	2200.00	1
1943	841.00	14	1040.00	20	1160.00	18	1270.00	18	1650.00	22	2930.00	30	3180.00	30	3390.00	30	4200.00	26
1944	720.00	9	980.00	11	1080.00	12	1140.00	15	1230.00	10	1350.00	9	1420.00	7	1430.00	5	1770.00	7
1945	860.00	15	1020.00	17	1070.00	10	1020.00	10	1300.00	13	1550.00	15	1620.00	13	1820.00	14	2410.00	18
1946	1080.00	25	1150.00	23	1390.00	23	1790.00	23	1850.00	26	2390.00	27	2510.00	26	3230.00	29	3550.00	30
1947	1190.00	26	1240.00	26	1290.00	22	1360.00	21	1610.00	21	1740.00	19	1850.00	18	1900.00	17	2270.00	15
1948	1320.00	28	1500.00	28	1720.00	28	1770.00	27	2090.00	28	2200.00	26	2730.00	24	2510.00	24	2780.00	23
1949	1450.00	29	1610.00	29	1720.00	29	1800.00	29	1900.00	27	2050.00	24	2130.00	23	2450.00	23	2510.00	21
1950	2040.00	31	2120.00	31	2310.00	31	2560.00	31	2600.00	31	2600.00	31	3870.00	31	3920.00	31	4260.00	31
1951	1480.00	30	1790.00	30	1980.00	30	2020.00	30	2160.00	30	2360.00	28	2690.00	29	2740.00	27	3070.00	28
1952	966.00	21	989.00	12	1020.00	8	1060.00	7	1100.00	4	1240.00	6	1370.00	5	1560.00	9	1920.00	9
1953	1010.00	22	1160.00	24	1250.00	20	1320.00	19	1420.00	17	1490.00	12	1810.00	17	1980.00	18	2000.00	10
1954	1040.00	23	1100.00	22	1100.00	16	1110.00	12	1170.00	8	1180.00	3	1200.00	2	1230.00	2	1430.00	3
1955	940.00	19	1030.00	18	1080.00	13	1100.00	11	1140.00	7	1190.00	4	1260.00	3	1250.00	3	1400.00	2
1956	884.00	17	1040.00	19	1070.00	11	1120.00	13	1200.00	9	1390.00	10	1430.00	8	1440.00	6	1650.00	6
1957	824.00	11	877.00	8	903.00	1	987.00	2	1010.00	1	1190.00	5	1550.00	11	1630.00	10	2080.00	13
1958	825.00	12	924.00	9	1100.00	9	1200.00	17	1500.00	18	1600.00	21	2270.00	25	2690.00	26	3060.00	27
1959	825.00	13	975.00	10	1090.00	14	1160.00	16	1370.00	15	1410.00	11	1450.00	9	1450.00	7	1900.00	8
1960	898.00	18	1000.00	14	1090.00	15	1130.00	14	1420.00	16	1750.00	19	1860.00	19	2070.00	19	2960.00	25
1961	1080.00	24	1220.00	25	1380.00	24	1460.00	22	1510.00	19	1640.00	17	1660.00	14	1710.00	13	2000.00	11
1962	1250.00	27	1350.00	27	1550.00	27	1630.00	26	1720.00	23	2050.00	25	2550.00	27	2430.00	25	3020.00	26
1963	860.00	16	1000.00	15	1250.00	21	1320.00	20	1570.00	20	1790.00	20	1760.00	16	1890.00	15	2410.00	19
1964	745.00	10	863.00	7	946.00	4	1010.00	4	1100.00	5	1120.00	1	1120.00	1	1190.00	1	1320.00	1
1965	707.00	7	857.00	6	930.00	2	1010.00	5	1130.00	6	1500.00	13	1570.00	12	1700.00	11	2660.00	12
1966	652.00	3	761.00	1	1050.00	9	1080.00	9	1250.00	11	1330.00	8	1400.00	6	1470.00	8	1590.00	5
1967	681.00	4	821.00	4	968.00	7	1050.00	6	1340.00	14	1600.00	16	1690.00	15	1900.00	16	2520.00	22
1968	627.00	1	1020.00	16	1220.00	19	1510.00	23	1760.00	24	2020.00	23	2050.00	20	2210.00	22	2300.00	16
1969	702.00	5	833.00	5	946.00	5	965.00	1	1090.00	2	1260.00	7	1540.00	10	1710.00	12	2170.00	14
1970	705.00	6	999.00	13	1360.00	23	1550.00	24	1770.00	25	1950.00	22	2100.00	27	2160.00	20	2330.00	17
1971	715.00	8	819.00	3	949.00	6	1070.00	8	1260.00	12	1500.00	14	2090.00	21	2210.00	21	2470.00	20

Figure A-2. Sample Low Streamflow Summary Printout (6).

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Meas. No. 451
Comp. by CRJ
Checked by _____

Sta. No. _____ DISCHARGE MEASUREMENT NOTES

Kanawha River @ Charleston, WV
Date 6-12, 1955 Party PSS
Width 915 Area 2200 Vel. 1.19 G.H. 18.57 Disch. 11,800
Method 2.42 No. secs. _____ G.H. change _____ in _____ hrs. Susp. 50
Method coef. 1.00 Hor. angle coef. 1.00 Susp. coef. 1.00 Meter No. 171010
Date rated 7-15-57 Used rating for rod _____ susp. Meter 9 ft
above bottom of wt. Tags checked _____ Spin before meas. Free after Free
Meas. plots _____ % diff. from _____ rating. Wading, cable, ice, boat, upstr., downstr., side
bridge between feet, mile, above, below gage Levels obtained _____

BASE GAGE READINGS				
Time	F	Recorder	Inside	Outside
1125	18.65	18.66	18.65	
1230	5	.68		
40		.68		
1300		.68		
20		.68		
40		.68		
1400	F	68		
1430	18.71	18.72		
Weighted M.G.H.		18.68		
G.H. correction		-.01		
Correct M.G.H.		18.67		

AUX. GAGE READINGS				
Time	F	Recorder	Inside	Outside
1050	19.82	19.85	19.82	
1230	5	.88		
40		.88		
1300		.88		
20		.88		
40		.90		
1400	F	.90		
1445	19.90	19.93		
Weighted M.G.H.		19.89		
G.H. correction		-.03		
Correct M.G.H.		19.86		

Check-bar, chain found _____ changed to _____ at _____
Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following conditions: Cross section _____

Flow slow-runs Weather cool
Other _____ Air _____ ° F. @ _____
Gage operating Water 22 ° F. @ _____
Record removed yes Intake flushed L
Observer _____

Control Slope
Remarks _____

G.H. of zero flow _____ ft. Sheet No. _____ of _____ sheets.

Figure A-3. Sample Form 9-275, Kanawha River at Charleston, WV (21).

KANAWHA RIVER BASIN

03169000 CLAYTOR RESERVOIR NEAR RADFORD, VA.

LOCATION.--Lat 37°04'28", long 80°35'05", Pulaski County, at Claytor Dam on New River, 0.5 mi (0.8 km) upstream from Little River, and 5.5 mi (8.8 km) upstream from Radford.

DRAINAGE AREA.--2,382 mi² (6,169 km²).

PERIOD OF RECORD.--May 1939 to current year (monthly figures only).

GAGE.--Water-stage recorder. Datum of gage is at approximately mean sea level (levels by Appalachian Power Co.). Prior to Sept. 11, 1943, nonrecording gage at same site and datum.

REMARKS.--Reservoir is formed by gravity overflow concrete dam. Spillway with crest at elevation 1,818.5 ft (554.28 m) is equipped with 9 lift gates 30 ft (9.1 m) high by 50 ft (15.2 m) wide. Dam completed and storage began May 22, 1939; water in reservoir reached minimum pool elevation in January 1940. Total level-pool capacity at elevation 1,847.0 ft (562.97 m), 1.5 ft (0.46 m) below top of gates, is 230,100 acre-ft (284 hm³) of which about 100,000 acre-ft (123 hm³) is controlled storage above minimum pool elevation of 1,820.0 ft (554.74 m), minimum pool. Reservoir is used for hydroelectric power and recreation.

COOPERATION.--Records furnished by Appalachian Power Co.

MONTHEND ELEVATION AND CONTENTS AT 2400, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975			
Date	Elevation (feet)	Contents (acre- feet)	Change in contents (acre- feet)
Sept. 30.....	1,845.65	224,000	-
Oct. 31.....	1,845.14	221,800	-2,200
Nov. 30.....	1,845.06	221,500	-300
Dec. 31.....	1,844.73	220,100	-1,400
CAL YR 1974.....	-	-	-300
Jan. 31.....	1,843.40	214,400	-5,700
Feb. 28.....	1,841.33	205,500	-8,900
Mar. 31.....	1,846.37	227,200	+21,700
Apr. 30.....	1,844.32	218,300	-8,900
May 31.....	1,845.20	222,100	+3,800
June 30.....	1,845.70	224,200	+2,100
July 31.....	1,845.11	221,700	-2,500
Aug. 31.....	1,845.80	224,700	+3,000
Sept. 30.....	1,844.62	219,600	-5,100
WTR YR 1975.....	-	-	-4,400

Figure A-4. Sample Reservoir Elevation-Capacity Data for an Impoundment (7).

1970 CENSUS OF POPULATION AND HOUSING Master Enumeration District List

1970
1980
COUNTY OF
TAB
CC
MCD/CCD
CODE
DESC
PLACE

STATE	FED STD COUNTY OF	COUNTY OF	CC	MCD/CCD	PLACE		BGA	URBANIZED AREA	TRACTED AREA	UNIV AREA		SEA	ESA	CBO	AREA NAME	TRACT	BASIC	SUFFIX	BLK/GRP	CODE	LWR	WARD	CD	HOUSING	POP	
					CODE	DESC				PREFIX	CODE															
51	54	121	121	1	016	0260	9	07				154079	03	026	1	CHRISTIANSBURG (CONT.)	7201									
51	54	121	121	1	016		7					154079	03	026	1	REMAINDER OF MCD (OR CCD)	7201									
51	54	121	121	1	021	0260	9	07				154079	03	026	1	SHAWVILLE DIST CHRISTIANSBURG	7201									
51	54	121	121	1	021		7					154079	03	026	1	REMAINDER OF MCD (OR CCD)	7201									
51	54	123	123	1	005		7					5720	154060	10	021	1	MANSEFORD	0709								
51	54	123	123	1	010	0600	9	05				5720	154060	10	021	1	CHUCKATUCK DIST CHUCKATUCK DIST	0709								
51	54	123	123	1	010	0735	9	05				5720	154060	10	021	1	CHUCKATUCK DIST CHUCKATUCK DIST	0709								
51	54	123	123	1	010	0970	9	05				5720	154060	10	021	1	CYPRESS DIST JERICHO (U)	0709								
51	54	123	123	1	010		9	05				5720	154060	10	021	1	JERICHO (U)	0709								
51	54	123	123	1	015	0635	9	01				5720	154060	10	021	1	LLOYD PLACE (U)	0709								
51	54	123	123	1	015	1045	9	03				5720	154060	10	021	1	LLOYD PLACE (U)	0709								
51	54	123	123	1	015		9	03				5720	154060	10	021	1	PLEASANT HILL (U)	0709								
51	54	123	123	1	015		9	03				5720	154060	10	021	1	PLEASANT HILL (U)	0709								
51	54	123	123	1	015		9	03				5720	154060	10	021	1	REMAINDER OF MCD (OR CCD)	0709								
51	54	123	123	1	015	0635	9	01				5720	154060	10	021	1	HOLY MECK DIST	0709								
51	54	123	123	1	015	1045	9	03				5720	154060	10	021	1	HOLLAND	0709								
51	54	123	123	1	015		9	03				5720	154060	10	021	1	SARATOGA PLACE (U)	0709								
51	54	123	123	1	015		9	03				5720	154060	10	021	1	REMAINDER OF MCD (OR CCD)	0709								

Figure A-5. Sample Enumeration District Data from 1970 Census (22).

LIST OF ACRONYMS

A. General

AF	Application Factor
BOD $\frac{20}{5}$	5-Day Biological Oxygen Demand at 20°C
EC50	Concentration at which 50% of a population incurs an effect
ED50	Dose at which 50% of a population incurs an effect
HRAM	Hazard Ranking and Allocation Methodology
H2OMOD	Subroutine for surface water pollutant fate in HRAM
LD50	Dose at which 50% of a population is killed
SMSA	Standard Metropolitan Statistical Area
SRICDM	Stanford Research Institute-adapted air dispersion model
TSTIA	Logic file for HRAM variable assignment
USGS	United States Geological Survey
UTM	Universal Traverse Mercator
7Q10	Low 7-day consecutive mean flow with 10 year recurrence expectancy
96LC50	Concentration of pollutant which causes estimated 50% fatalities in a fish population after 96 hours exposure

B. HRAM-Specific

b	Blank space
che	Pollutant identification field, non-specific
eff	Effect identification field, non-specific
loc	Location identification field, non-specific
med	Medium identification field, non-specific
nnn	Population index identification field, non-specific
pop	Population type identification field, non-specific

AIR	Medium identification - air
ATX	Acute toxic effect
B	Threshold for dose-risk curve
C	Concentration or carcinogenic effect
CFS	Chronic fish effect
CPS	Crops population identifier
CTG	Severe chronic effect
CTR	Mild chronic effect
CYL	Crop loss effect
FKL	Fish kill (acute exposure) effect
FSH	Fish population identifier
GWT	Medium identification-groundwater
HUM	People population identifier
H2O	Medium identification - surface water flow
LMD	First-order disappearance rate constant of pollutant
N	Population data identifier
Q	Pollutant discharge rate
R	Remaining fraction of pollutant in water after treatment
S	Slope of dose or concentration - risk relation
SMB	Dose-concentration conversion factor
SMC	Unit air pollutant discharge - concentration conversion factor
SMF	Surface water flow
SMT	Surface water travel time
U	Uncertainty
V	Value

C. Other Variables

f	Fraction plant production capacity
p(c)	Probability that a chemical is a carcinogen
q	Use or production rate of a chemical
D	General numerical datum
F	Wastewater flow from a production facility
L	Characteristic concentration or dose from toxicological data
P	Potency of chemical as a potential carcinogen

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